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STATIC TEST PROGRAM FOR CH-47A HELICOPTER

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AIR FORCE FLIGHT DYNAMICS LABORATORY
RESEARCH AND TECHNOLOGY DIVISION
AIR FORCE SYSTEMS COMMAND
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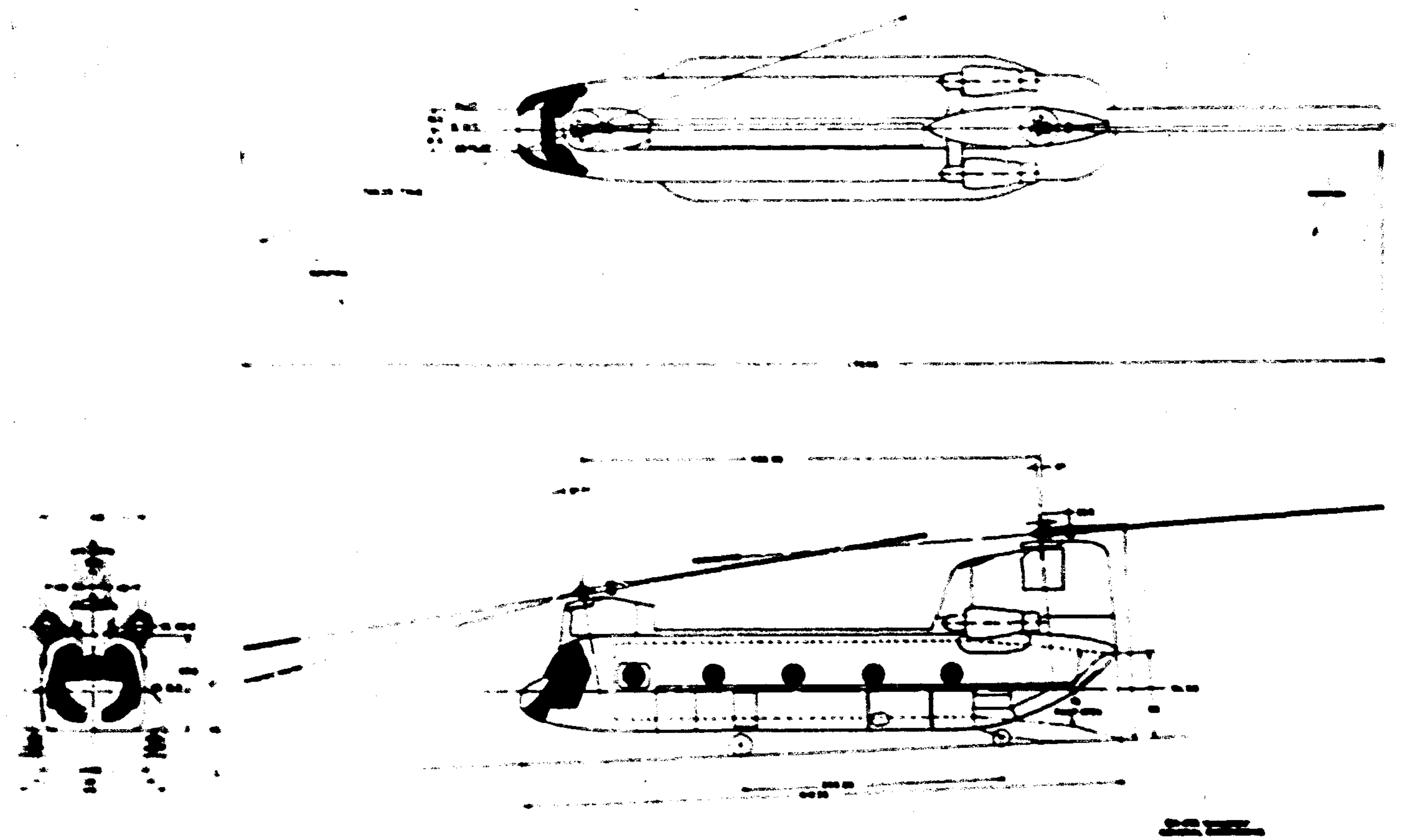

Three Views of CH-47A Helicopter

FOREWORD

This internal report was prepared by the Air Force Flight Dynamics Laboratory as a formal record of the structural test program conducted on the Vertol CH-47A helicopter. The structural tests reported were conducted by the Structures Division of the Air Force Flight Dynamics Laboratory at Wright-Patterson Air Force Base, Ohio, with Mr. Robert L. Schneider acting as project test engineer. Mr. Thomas F. Hughes, senior project test engineer of the Structures Division and Mr. Stanley Skibo of the Vertol Division of Boeing Aircraft Company assisted in the program. Messrs. Earl J. Hartzell and Chalmer D. Cruze were responsible for all instrumentation.

This is the final report for the project.

ABSTRACT

Results of structural tests conducted on the complete airframe of the Vertol CH-47A helicopter covering all critical flight, landing, take-off, and ground handling conditions are presented in this report. Two critical test conditions for growth potential are also presented.

The structure of the Vertol CH-47A helicopter, with the exception of the litter and troop seat installations, was capable of withstanding the static ultimate loads generated by 71 different test conditions.

This technical documentary report has been reviewed and approved.

W. A. SLOAN, JR.
Colonel, USAF
Chief, Structures Division
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LIST OF SYMBOLS AND ABBREVIATIONS

C.G.	center of gravity
MACG	most aft center of gravity
MFCG	most forward center of gravity
NCG	normal center of gravity
Fwd	forward
BL	buttock line
FS	fuselage station
Ult.	ultimate
psi	pounds per square inch
lbs/sq ft	pounds per square foot
FDTT	AF Flight Dynamics Laboratory, Structures Division, Structures Test Branch
DUL	design ultimate load
RTV	room temperature vulcanizing
WL	water line
N_x	load factor in the x axis
N_y	load factor in the y axis
N_z	load factor in the z axis
x	angular acceleration about the x axis
y	angular acceleration about the y axis
z	angular acceleration about the z axis

INTRODUCTION

The Vertol CH-47A helicopter was subjected to a complete static test program that covered all of the critical flight, landing, take-off, ground handling, and crash conditions.

At the completion of the test program two growth tests were conducted. The results of these tests demonstrated that the CH-47A basic structure has approximately 40 percent more inherent strength than was assumed in the original stress analysis.

Several structural failures and design deficiencies were encountered during the test program. These structural deficiencies and the corresponding recommended changes are discussed in the section on Test Conditions, Dates of Tests, and Test Results. With these deficiencies corrected, the CH-47A helicopter is structurally capable of withstanding the static ultimate loads generated by the conditions outlined in the Appendix.

TEST ARTICLE AND LOAD APPLICATION METHODS

The test article consisted of a complete CH-47A airframe. A floating test set-up was used for all major structural tests. In this procedure, the entire airframe is tested as one integral unit, with the dead weight of the structure and all attached test fixtures relieved by lead weights suspended from pulleys and attached to the test article. This effectively puts the structure in a zero "g" condition. All test loads were required to be perfectly balanced in translation, roll, pitch, and yaw. (See Figures 1 through 3.)

Several methods were used in applying the test loads to the fairings and nose enclosure. Neoprene sponge rubber tension pads and metal-to-metal tension plates bonded to the surface with General Electric RTV silicones were used for introducing tension loads to the skin (Figure 4). Cables were attached to each of these loading points and were interconnected to produce particular loading distributions by means of aluminum "whiffle trees." The tension loading on the engine cowling was accomplished by an arrangement of air bladders (Figure 5). Bladders placed in a wooden enclosure and held against the structure were used for compressive air load tests (Figure 6). In all other test conditions not requiring air loads, the loads were applied by means of hydraulic rams or struts. Major components such as engines, transmissions, and rotor groups were loaded independently through direct attachment fittings. Pallets were used for frame and cargo loading in the center fuselage section (Figure 7). Aluminum tension straps, bonded to the skin with RTV silicones, were used for introducing loads to the fuselage frames forward of the forward splice and aft of the aft splice (Figure 8). Test-load control was accomplished with Edison Hydraulic Load Maintainers and manual hydraulic control units. The manual units were used primarily for control of pitch, roll, and yaw in the floating test set-up. A valve was installed on the Edison units to rapidly reduce the applied loads to zero in the event of a structural failure occurring during a test condition.

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The test article was loaded in 10 percent increments up to 67 percent design ultimate load (DUL), then was loaded in 5 percent increments up to 100 percent DUL. Deflection and strain gage data were recorded from 20 percent through 90 percent DUL in 10 percent increments.

INSTRUMENTATION

The strain gage installation on the CH-47A helicopter was accomplished by a joint effort of FDTT and Vertol. Approximately 400 Bud Company C12-141 and C12-121 gages (foil, epoxy backed gages which are temperature-compensated for aluminum) were installed. Critical strain gage and deflection transducer locations were selected prior to each test condition. Strains were recorded at selected incremental percentages of DUL while deflections were recorded continuously or at the same increment as strain. Critical applied loads were monitored with calibrated load cells to insure accurate loading, to eliminate overloads, and to determine the actual percent of load at which a failure occurred. Nosker Engineering Products Strain Indicators (Model 2A), which had been modified so as to be compatible with a Gilmore Industries Graphical Recorder-Plotter (Model 114), were used to monitor strains. This system was capable of automatically plotting 144 data channels at a rate of one sample per channel per second. The total system accuracy (from the strain gage to the recording instrument) was ±5 percent of full scale, "full scale" being the full scale range used or 5000 micro inches of strain. Deflections were monitored by a system comprised of Research, Incorporated Displacement Transducers (Models 4040 and 4046), Research, Incorporated Transducer Control Cabinet (Model 4095), and a Research, Incorporated Recorder-Controller (Model 4080). The total system accuracy was ±1 percent of full scale.

DESCRIPTION OF STRUCTURE

The Vertol CH-47A helicopter has twin rotors arranged in tandem fashion. The front rotor is supported by the front pylon structure, which is located directly above and aft of the fuselage cockpit; and the aft rotor, supported by the aft pylon, is located at the extreme aft end of the fuselage. The helicopter is equipped with a fixed quadricycle type alighting gear, consisting of a fixed vertical type for the forward gear and an aft landing gear having full castering capability.

The forward transmission and rotor group are suspended by four fittings, one on each side of a box-type super structure extending from the crown of the ship.

NOTE: A detailed description of recording instruments, transducer characteristics, methods of installation, type of output information, and transducer locations on the CH-47A are available to contractors through the Air Force Flight Dynamics Laboratory, FDTT.

The primary structure of the fuselage is a semi-monocoque construction with supplementary structural members provided in the vicinity of open sections and at those locations where large concentrated loads are introduced. The semi-monocoque structure consists primarily of the following: (1) longitudinal members to provide bending restraint in the fuselage; (2) metal skin to carry the fuselage shear and torsion; and (3) transverse frames and bulkheads to provide stiffness in the skin structure and to maintain the fuselage cross section during flexure.

The fuselage skins consist of 2024 aluminum alloy alclad sheet for the top and side skins, while 7075 aluminum alloy alclad sheet is used on the bottom portion.

The aft pylon consists of an upper and lower section. The primary structure in the upper portion is a closed box form, bounded on top by the thrust deck, on the bottom by the torque deck (WL 72), at the ends by bulkheads at Station 482 and 594, and along the sides by the skins. The primary structure below WL 72 consists of two open end frames (Stations 440 and 482) and the crown and side skins.

TEST CONDITIONS, DATES OF TESTS, AND TEST RESULTS

During 81 tests run, the CH-47A was subjected to 71 different test conditions. These test conditions are explained in Tables 1 through 6 (Appendix) and include conditions for flight, landing, air load, flight controls, components, and ground handling. In the listing which follows, some test numbers are preceded by an asterisk. Explanations of tests so marked follow the listing.

Tests	CH-47A Test Condition	Test Date	Ultimate Load Supported (%)
1	Flight control system cond. No. 7	7 June 1962	100
2	Flight control system cond. No. 8	7 June 1962	100
3	Flight control system cond. No. 1	8 June 1962	100
4	Flight control system cond. No. 2	8 June 1962	100
5	Flight control system cond. No. 3	8 June 1962	100
6	Flight control system cond. No. 4	11 June 1962	100
7	Flight control system cond. No. 5	11 June 1962	100
8	Flight control system cond. No. 6	12 June 1962	100
9	Flight control system cond. No. 9	18 June 1962	100
*10	Flight control system cond. No. 11	20 June 1962	94
11	Flight control system cond. No. 10	20 June 1962	100

Tests	CH-47A Test Condition	Test Date	Ultimate Load Supported (%)
12	Flight control system cond. No. 12	21 June 1962	100
*13	Flight control system cond. No. 11	28 June 1962	85
14	Escape panel airload test	6 July 1962	100
15	Flight control system cond. No. 14	20 July 1962	100
16	Flight control system cond. No. 15	23 July 1962	100
17	Flight control system cond. No. 13	23 July 1962	100
18	Load-deflection test No. 1	11 September 1962	N/A
19	Cockpit enclosure unsymmetrical flight cond.	28 September 1962	100
20	Cockpit enclosure symmetrical flight cond.	4 October 1962	100
21	Main cabin door air load test	11 October 1962	100
22	Leading edge fairing of aft pylon	18 October 1962	100
23	Forward pylon fairing	30 October 1962	100
24	3B MACG 33000 pounds gross weight	4 February 1963	100
25	3B MACG 27100 pounds gross weight	13 February 1963	100
26	6B MACG 27100 pounds gross weight	1 March 1963	100
27	7B MCG 33000 pounds gross weight	5 March 1963	100
28	2B MFCG 33000 pounds gross weight	11 March 1963	100
29	2B MFCG 27100 pounds gross weight	12 March 1963	100
*30	External cargo tow hook	3 April 1963	67
31	External cargo hook	16 April 1963	100

Tests	CH-47A Test Condition	Test Date	Ultimate Load Supported (%)
32	Main landing gear cond. VC (50-50 distribution)	30 April 1963	100
33	Main landing gear cond. VC (60-0 distribution)	1 May 1963	100
*34	Main landing gear cond. VB	3 May 1963	97
35	Engine cowling airload test	3 May 1963	100
36	Aft gear towing condition	8 May 1963	100
37	Forward gear landing cond. IVD (60-0 distribution)	17 May 1963	100
38	Forward gear landing cond. IVD (50-50 distribution)	20 May 1963	100
39	Forward gear towing condition	23 May 1963	100
40	External cargo hook (track beam assembly)	28 May 1963	100
41	Rescue hoist	3 June 1963	100
*42	Hoisting condition	5 June 1963	92
43	FWD transmission and rotor group 8G down crash cond.	11 June 1963	100
44	Troop commander seat side load	13 June 1963	100
45	Crew seats - 8G down crash cond.	14 June 1963	100
46	Troop commander seat (back load)	14 June 1963	100
47	Crew seats - 8G side crash cond.	17 June 1963	99
48	Troop commanders seat max. down load	17 June 1963	100
49	Troop commanders seat lap belt load	24 June 1963	125
50	Troop seat lap belt load	24 June 1963	135
51	One man seat lap belt load	25 June 1963	100

Tests	CH-47A Test Condition	Test Date	Ultimate Load Supported (%)
52	5000 pound cargo tie-down supports Test No. 1	26 June 1963	100
53	5000 pound cargo tie-down supports Test No. 2	26 June 1963	100
54	10000 pound cargo tie-down supports Test No. 1	26 June 1963	100
55	10000 pound cargo tie-down supports Test No. 2	26 June 1963	100
56	Litter 4.5G down crash cond.	1 July 1963	100
57	Litter 1.5G side crash cond.	2 July 1963	100
58	Cargo ramp and support structure	2 July 1963	100
*59	Litter 8G forward crash cond.	2 July 1963	62
60	Cargo handling	8 July 1963	100
61	Engine 8G Fwd crash condition	12 July 1963	100
62	Engine 8G down crash cond.	12 July 1963	100
63	Engine 8G side crash condition	15 July 1963	100
64	Main combining transmission 8G Fwd crash	15 July 1963	100
65	Main combining transmission 8G down crash	15 July 1963	100
66	Main combining transmission 8G side crash	16 July 1963	100
*67	Hoisting condition	17 July 1963	100
68	Aft transmission and rotor group 8G down crash	18 July 1963	100
69	Aft transmission and rotor group 8G Fwd crash	22 July 1963	100
70	Fwd transmission and rotor group 8G Fwd crash	23 July 1963	100

Tests	CH-47A Test Condition	Test Date	Ultimate Load Supported (%)
*71	Flight control system cond. 11	26 July 1963	100
*72	Crew seats-8G Fwd crash cond.	26 July 1963	80
*73	Crew seats-8G Fwd crash cond.	29 July 1963	125
*74	2B MFCG 33000 pounds gross weight	6 August 1963	140
*75	3B MACG 33000 pounds gross weight	12 August 1963	140
*76	Litter 8G Fwd crash cond.	14 August 1963	72
*77	External cargo tow hook	20 August 1963	100
78	Max. floor load	23 August 1963	100
*79	Troop seat 8G side load	26 August 1963	80
*80	Troop seat 8G down load	27 August 1963	90
*81	Landing cond. VC (new shear web installed)	27 September 1963	127

Tests 10, 13, and 71

During the test of flight control system condition No. 11, a failure occurred at 94 percent DUL. The 114C1013-8 push-pull rod failed in compression. The boost pressure at the time of failure was 1500 psi. A similar rod was tested with a boost pressure of 2250 psi. The rod failed in compression at 85 percent DUL. A new rod was designed with a greater wall thickness and retested. The system satisfactorily supported 100 percent DUL with the new rod (114C1013-33). (Figures 11 and 12.)

Tests 30 and 77

During the test of the external cargo hook, several strain gage readings were above the allowable indicated by Vertol at 67 percent DUL. Further analysis indicated that the original allowable strain was too low, therefore the external cargo hook was retested and satisfactorily supported 100 percent DUL without failure.

Test 34

The aft landing gear shear box failed at 97 percent DUL in condition VB (Figures 13 and 14). This was the third major test on this gear and there were shear wrinkles prior to this test. The structure is considered satisfactory in view of damage incurred during the previous tests.

Tests 42 and 67

During the hoisting condition, a failure occurred in the aft crown beam installation at 92 percent DUL (Figures 15 and 16). The main web of the aft crown beam installation (Part No. 114-S-3351) was strengthened and the condition was retested to 100 percent DUL.

Tests 59 and 76

During the litter 8G forward crash condition, a failure occurred in the litter stanchion at 62 percent DUL (Figure 17). During retest, with the lower plate of the stanchion increased in thickness, a failure occurred in the litter strap floor attachment fitting at 72 percent DUL (Figures 18 and 19). Further tests are necessary to prove the litter installation satisfactory.

Tests 72 and 73

At 80 percent DUL, a failure occurred in the sliding leg of the crew seat during the 8G Fwd crash condition (Figure 20). This failure was due to the position of the seat, in that it allows only partial contact of the shoulder of the seat leg with the seat track flanges when the seat is in the most forward position (Figure 21). The seat was placed one inch aft of its most forward position and satisfactorily retested to 125 percent DUL. It was recommended that the seat adjustment be relocated to prevent the seat from being placed in the present extreme forward position.

Test 74

Condition 2B MFCG 33000 pounds gross weight was tested to 140 percent DUL for a growth potential indication. This condition is critical for the forward pylon and splice, as indicated in the Appendix. The structure supported 140 percent DUL after the forward transmission support structure (Part No. 114S1105-193) was restrained from buckling at 125 percent DUL. Only minor damage was noted (Figure 22).

Test 75

Condition 3B MACG 33000 pounds gross weight was tested for growth potential. This condition is critical for the aft pylon, as indicated in the Appendix. The following failures occurred at 140 percent DUL:

(a) Failure of frames 555, 575.5, and 594 (Figure 23);
(b) Failure of longeron 114S3356-17 (Figure 24);
(c) Skin tear and permanent buckle at F.S. 594 (Figures 25 and 26);
(d) Failure of frame 534 (Figures 27 and 28);
(e) Failure of ramp fairing aft of F.S. 482 (Figure 29).

Tests 79 and 80

During the troop seat 8G side load, a failure occurred in the leg strap of the seat at 80 percent DUL. The back panel of the troop seat was against the fuselage at 40 percent.

The seat back straps failed at 90 percent DUL during the troop seat 8G down crash condition. The troop seat back-up structure could not be tested to the 8G load conditions because the existing troop seats are designed to a lower "G" limit than the back-up structure. In testing the back-up structure, a troop seat must be used so as to distribute the load correctly throughout the back-up structure.

Test 81

The aft landing gear condition Vc was retested with a new shear web installed. The drag link on the main gear forging (Part No. 114L 2029-1) failed at 127 percent DUL (Figures 30, 31, and 32). The new web installation was permanently wrinkled (Figure 33).

CONCLUSIONS AND RECOMMENDATIONS

Based on the results and observations obtained from the CH-47A Static Test Program, the following conclusions and recommendations are presented.

1. As a result of static test failures or deficiencies encountered during the test program, FDTT recommends that the changes indicated in Tests 10, 42, 59, and 72 (preceding section) be incorporated on all CH-47A service helicopters.

2. In the event that a troop seat is designed to take a greater load than the existing troop seat, it is recommended that the back-up structure be tested to DUL with this seat (reference Test 79, preceding section).

3. The results of the growth testing indicate that the basic fuselage structure of the CH-47A has approximately 40 percent more inherent strength than was assumed in the original design stress analysis. However, the forward transmission support structure required additional stiffening. The reader should note that the landing gear and other components have not been tested for overloads.

4. In general, the measured stresses recorded during the tests were less than those predicted by stress analysis.

5. With the incorporation of all the structural changes recommended in this report, the CH-47A Helicopters are capable of supporting the static ultimate loads for all of the conditions listed in the Appendix.

6. From test data and observations, the areas with the lowest margins of safety, although they supported 100 percent DUL are: (a) The upper forward corner of the main cabin door; (b) and the aft landing gear back-up structure.

APPENDIX

CH-47A STRUCTURAL TEST CONDITIONS

TABLE 1

CH-47A FLIGHT CONDITIONS TESTED

(Load Factors Listed Below Are Ultimate)

Test Conditions	Gross Wt (Lbs)	C. G.	N_x	N_y	N_z	x	y	z	Critical Areas
Condition 2B--symmetrical dive and pull-out nose up pitching	33,000	MFCG	.406	0	3.07	.013	4.12	-.285	Fwd pylon and Fwd splice, critical in vertical bending
Condition 2B--symmetrical dive and pull-out nose up pitching	27,100	MFCG	.541	0	4.087	-.003	4.203	.268	Rotor loads
Condition 3B--symmetrical dive recovery from pull-out, nose down pitching	33,000	MACG	-.757	0	2.93	-.108	-3.56	.295	Aft pylon critical in vertical bending
Condition 3B--symmetrical dive recovery from pull-out, nose down pitching	27,100	MACG	-1.0	0	3.91	-.171	4.96	.295	Rotor loads
Condition 6B--yawing (nose to the right)	27,100	MACG	-.453	.066	3.97	2.52	0	-2.11	Fuselage lateral bending and torsion
Condition 7B (gust condition)	33,000	NCG	-.374	0	3.28	0	0	0	Maximum bending between fuselage station 300 to 350

TABLE 2
CH-47A LANDING CONDITIONS TESTED

Test Conditions	Gross Wt. (Lbs)	C.G.	Critical Areas
Condition VC side obstruction 50-50 distribution	27,100	MACG	Aft gear and back-up structure (shear box)
Condition VC side obstruction flat tire condition 60-0 distribution	27,100	MACG	Aft gear axle
Condition VB aft obstruction	27,100	MACG	Aft gear and back-up structure (shear box)
Condition IVD side obstruction 50-50 distribution	27,100	MFCG	Fwd gear and back-up structure
Condition IVD side obstruction flat tire condition 60-0 distribution	27,100	MFCG	Fwd gear axle

TABLE 3
AIR LOAD CONDITIONS TESTED

Test Condition	Velocity (Knots)	Yaw (Degrees)	Angle of Attack (Degrees)	Critical Area
Cockpit enclosure--symmetrical flight condition	183	0	-1.7	Cockpit enclosure
Cockpit enclosure--unsymmetrical flight condition	159	15	-1.7	Cockpit enclosure
Forward pylon fairing	145	20	-1.7	Work platform 114S1901
Leading edge fairing of aft pylon	159	15	-2.5	Leading edge doors
Escape panel	183	5	-1.7	Panel moulding
Main cabin door	183	5	-1.7	Door moulding and attachments
Engine cowling	183	0	0	Engine inspection door

TABLE 4
FLIGHT CONTROLS TEST CONDITIONS

Test Condition	System	Effort	Load Application Point	Control Position	Ultimate Load (Lbs)
1	Longi-tudinal	Single pilot	Pilot's hand grip	Fwd	300
2	Longi-tudinal	Single pilot	Pilot's hand grip	Aft	300
3	Lateral	Single pilot	Pilot's hand grip	Left	150
4	Lateral	Single pilot	Pilot's hand grip	Right	150
5	Collec-tive	Single pilot	Pilot's hand grip	Down	225
6	Collec-tive	Single pilot	Pilot's hand grip	Up	225
7	Direc-tional	Single pilot	Pilot's right pedal	Right pedal aft	450
8	Direc-tional	Single pilot	Pilot's left pedal	Left pedal aft	450
9	Longi-tudinal	Dual pilot plus boost	Sticks	Fwd	225 each
10	Lateral	Dual pilot plus boost	Sticks	Left	112.5 each
11	Collec-tive	Dual pilot plus boost	Sticks	Up	169 each
12	Direc-tional	Dual pilot plus boost	Right pedals	Right pedals aft	337.5 each
13	Rotor and flt. controls	N/A	Fwd rotorhead Aft rotorhead		3100 3100
14	Rotor and flt. controls	N/A	Fwd rotorhead Aft rotorhead		2910 796
15	Rotor and flt. controls	N/A	Fwd rotorhead Aft rotorhead		0 796

TABLE 5
COMPONENT TEST CONDITIONS

Test Condition	Ultimate Load (Lbs)
Engine 8G Fwd crash condition	6656 per engine
Engine 8G down crash condition	6656 per engine
Engine 8G side crash condition	6656 per engine
Forward transmission and rotor group 8G down crash condition	22139
Forward transmission and rotor group 8G Fwd crash condition	22139
Main combining transmission 8G side crash condition	2574
Main combining transmission 8G down crash condition	2574
Main combining transmission 8G Fwd crash condition	2574
Aft rotor group and transmission 8G down crash condition	25106
Aft rotor group and transmission 8G Fwd crash condition	25106
Crew seat 8G Fwd crash condition	1920
Crew seat 8G side crash condition	1920
Crew seat 8G down crash condition	1920
Troop seat supporting structure (lap belt load)	2030 per seat
Troop seat 8G side load	2080 per seat
Troop seat 8G down load	2080 per seat
One man seat lap belt load	2030
Troop commander seat (maximum down load)	2000
Troop commander seat side load	225
Troop commander seat (back load)	600
Troop commander seat lap belt load	1500

TABLE 5 (CONT'D)

Test Condition	Ultimate Load (Lbs)
Litter installation supports 1.5G side load	375 per litter
Litter installation supports 4.5G down load	1125 per litter
Litter installation supports 8G Fwd load	2000 per litter
Rescue hoist	1800
Cargo handling	4300
External cargo hook (back-up structure)	48,000
External cargo hook (track bean assembly)	48,000
External tow hook	69,212
Cargo ramp	9000
Hoisting condition	60,000
Cargo tie-down supports (10,000 pound fitting)	10,000 (45 deg. aft)
Cargo tie-down supports (10,000 pound fitting)	10,000 (3 deg. aft)
Cargo tie-down supports (5000 pound fitting)	5000 (45 deg. aft)
Cargo tie-down supports (5000 pound fitting)	5000 (3 deg. aft)
Max. floor loading 300 pound per square foot 7G	2100 PSF

TABLE 6
GROUND HANDLING CONDITIONS TESTED

Test Condition	Tow Load (Lbs ULT)	Vertical Load (Lbs ULT)
Forward Gear Towing Condition	10,422	19,725
Aft Gear Towing Condition	8,334	9,648

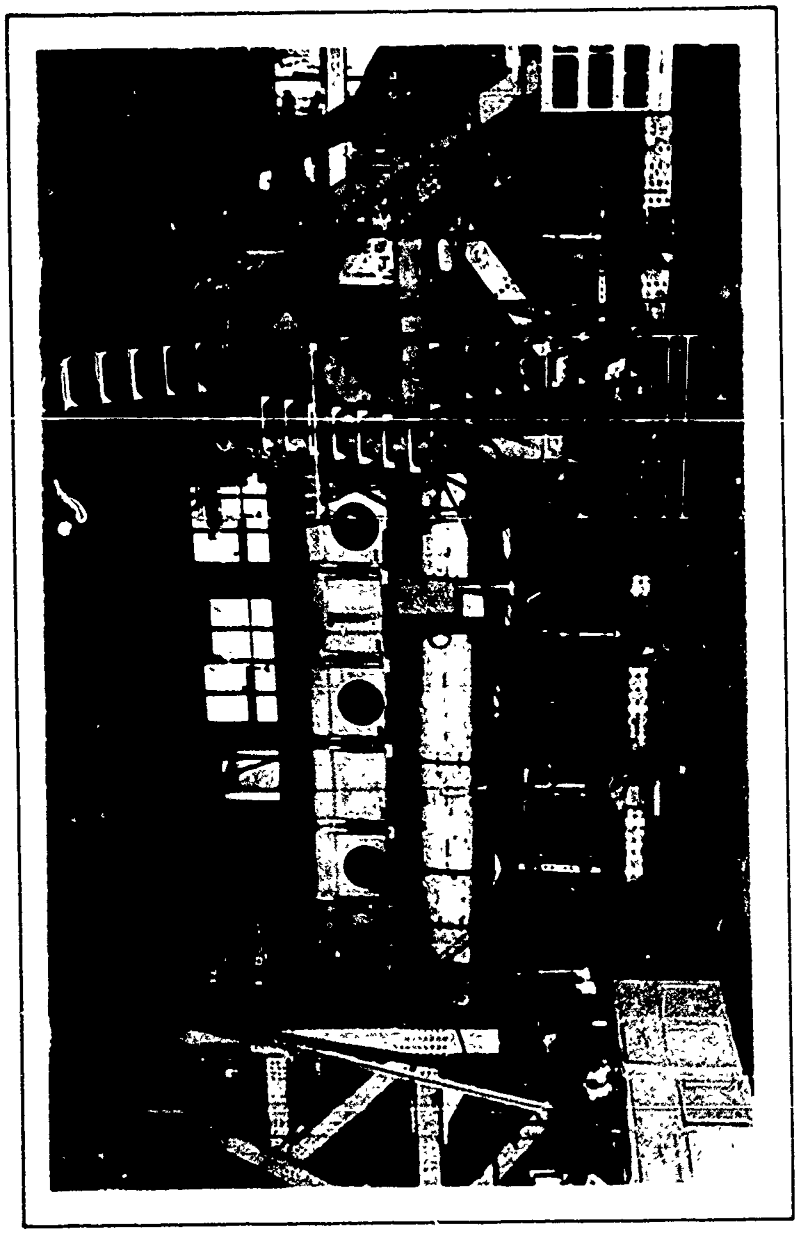

Figure 1. Structure Dead Weight Relief System

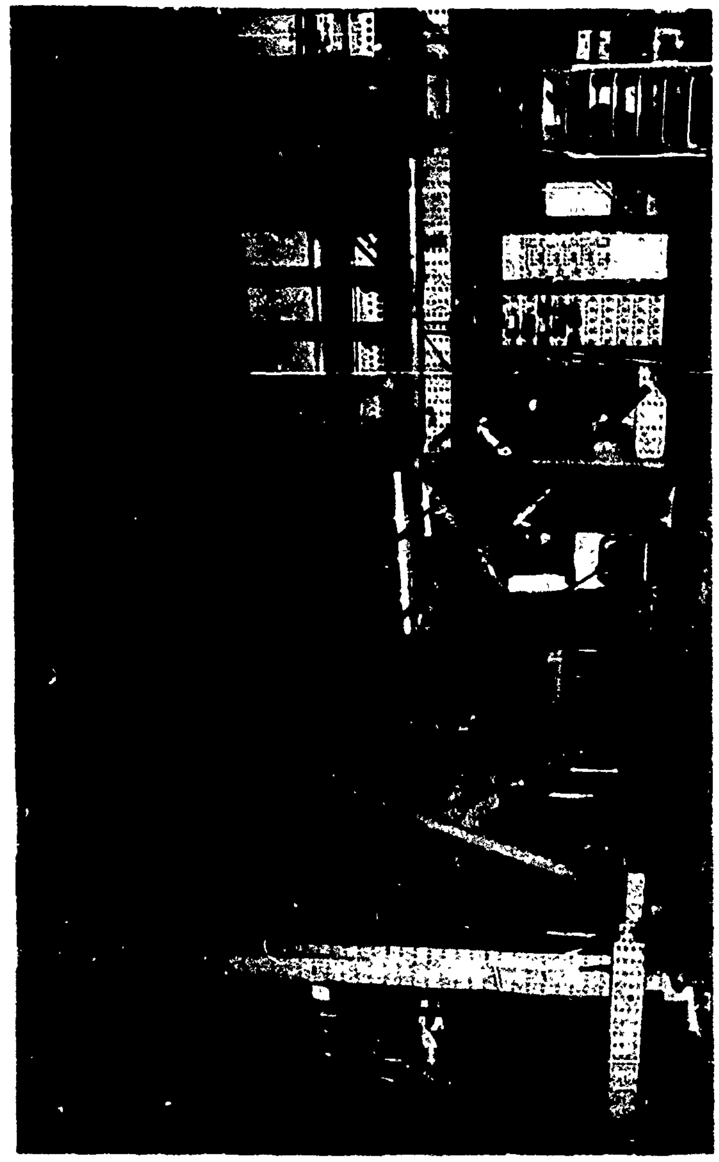

Figure 2. Basic Test Set-Up

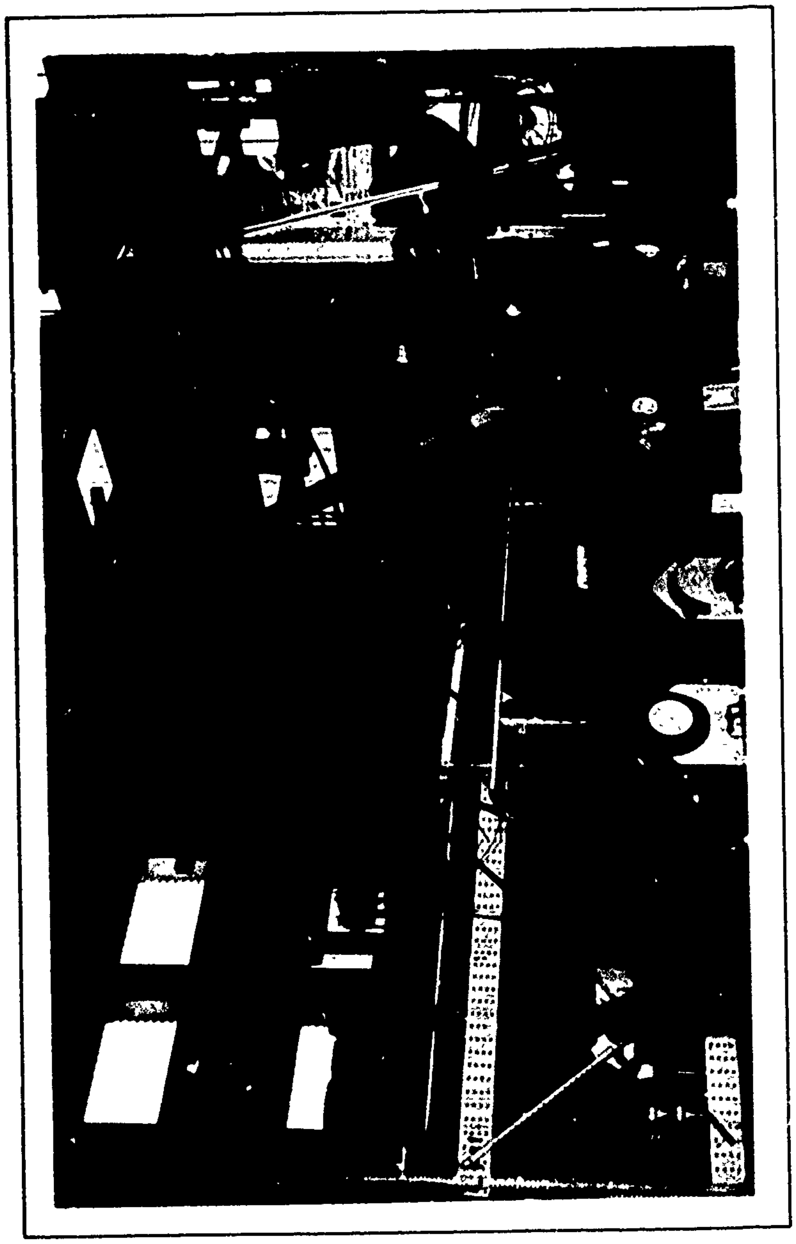

Figure 3. Basic Test Set-Up

Figure 4. Load Patches

Figure 5. Typical Air Bladders Used for Loading

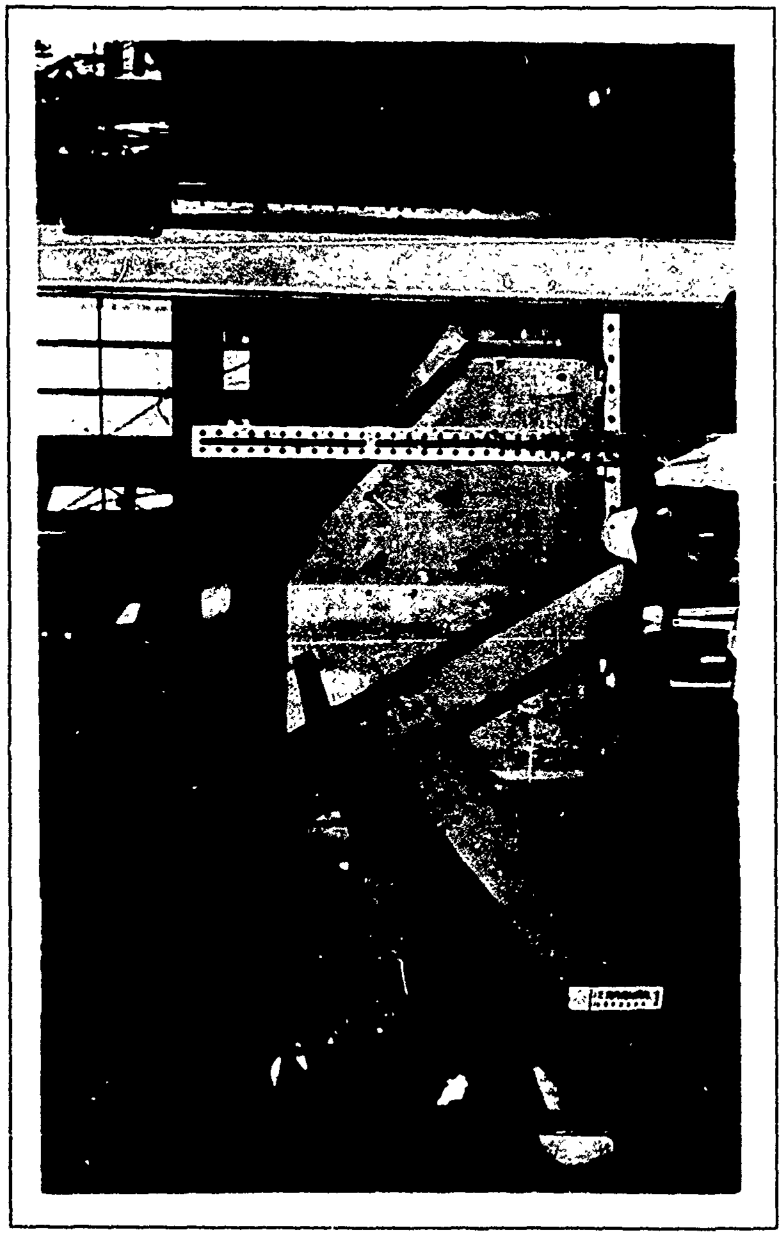

Figure 6. Typical Structure Used for Containing the Loading Bladders

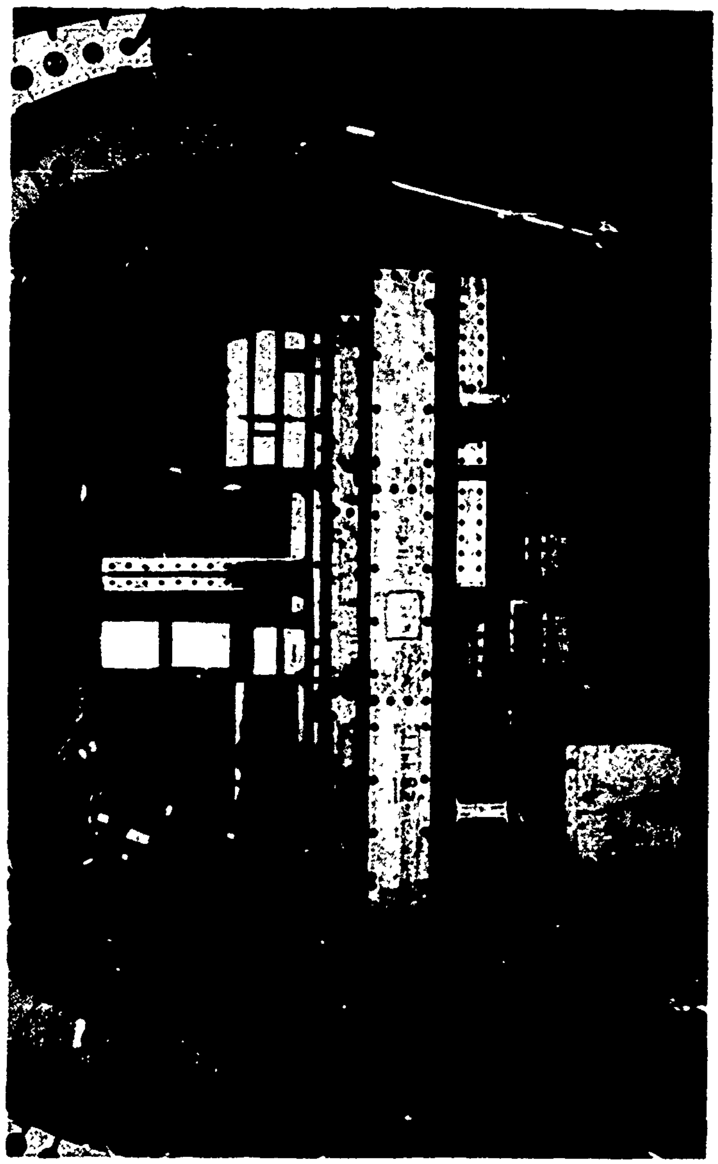

Figure 7. Pallets Used for Floor Loading

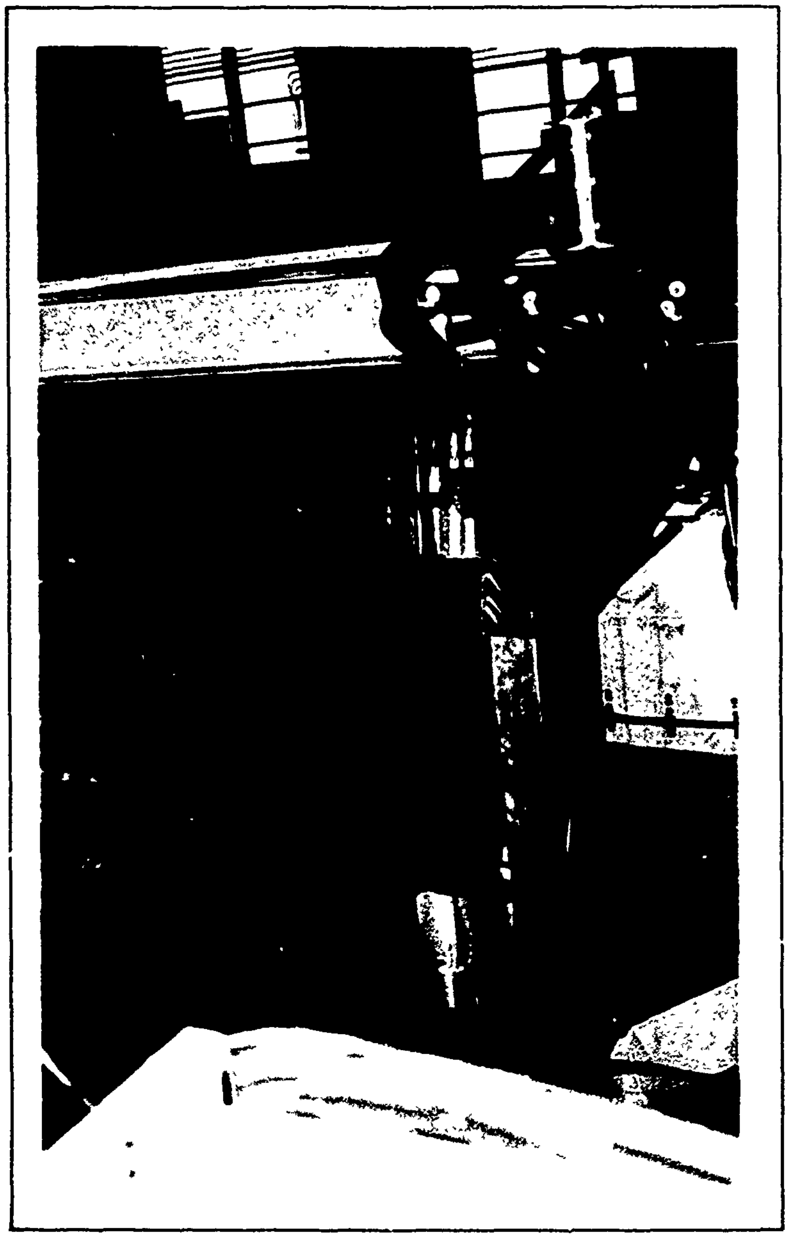

Figure 8. Typical Loading Straps Bonded by RTV Silicone Adhesives

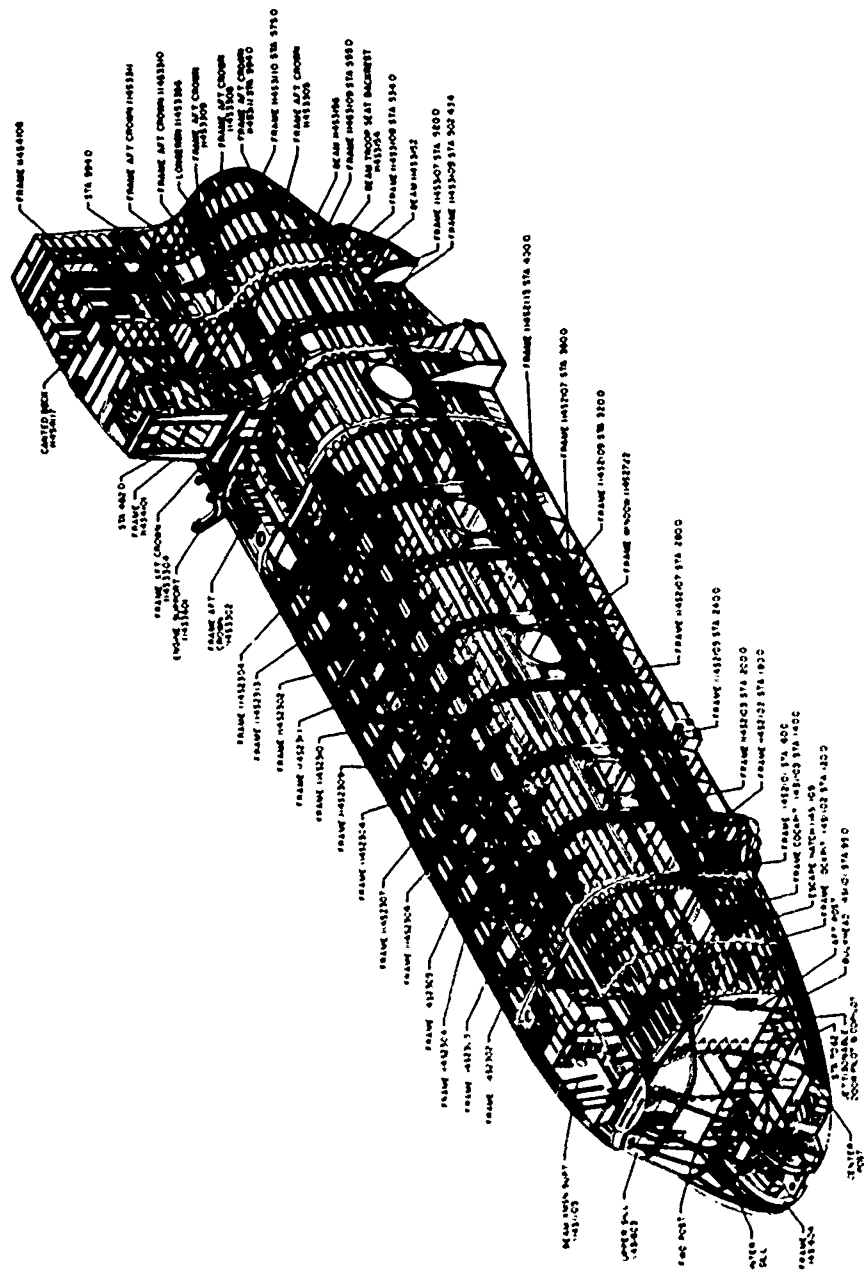

Figure 9 CH-47A Structural Schematic

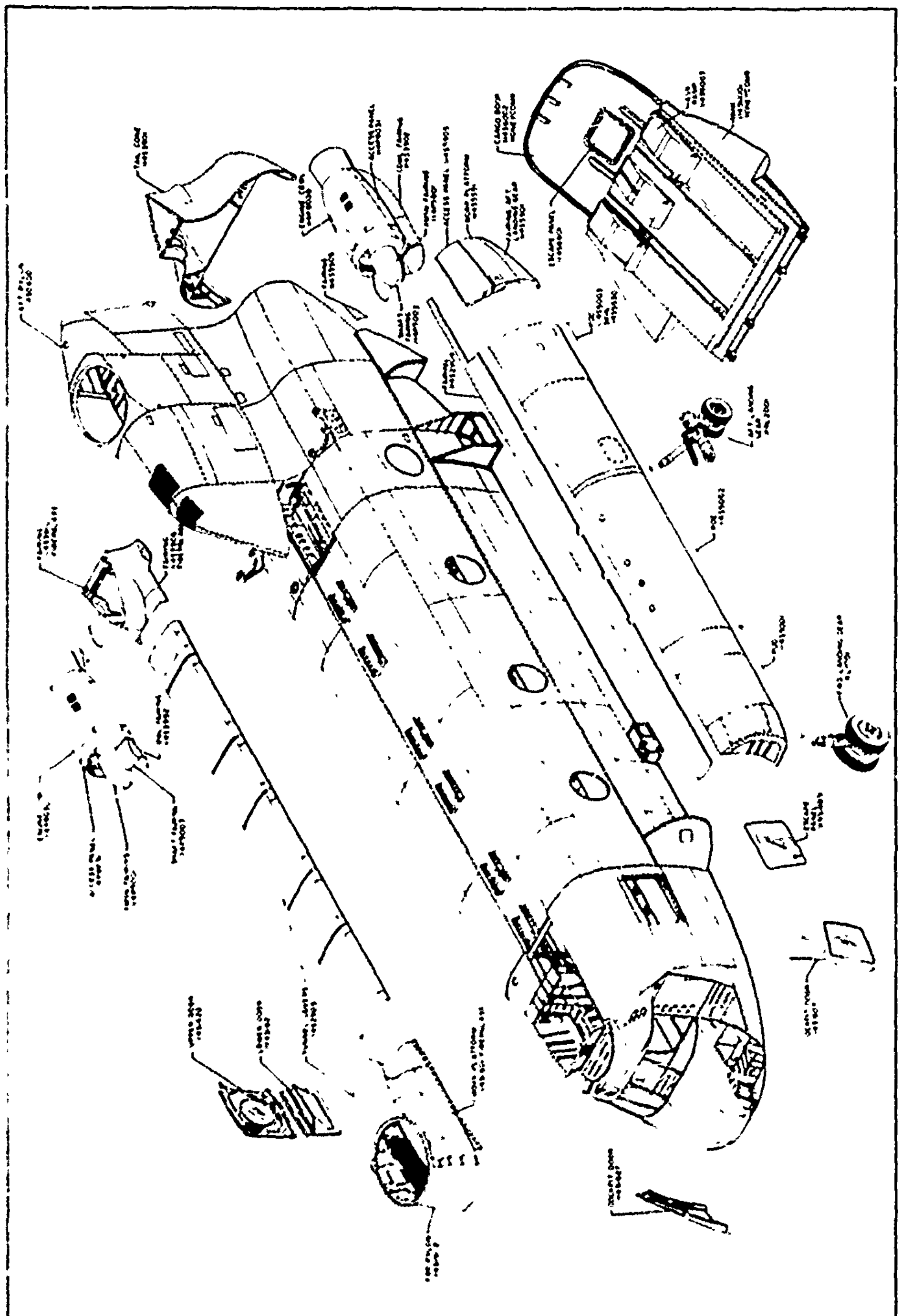

Figure 10. Exploded View of CH-47A Helicopter

Figure 11. Failure of 114C1013-8 Link Assembly at 85 percent DUL

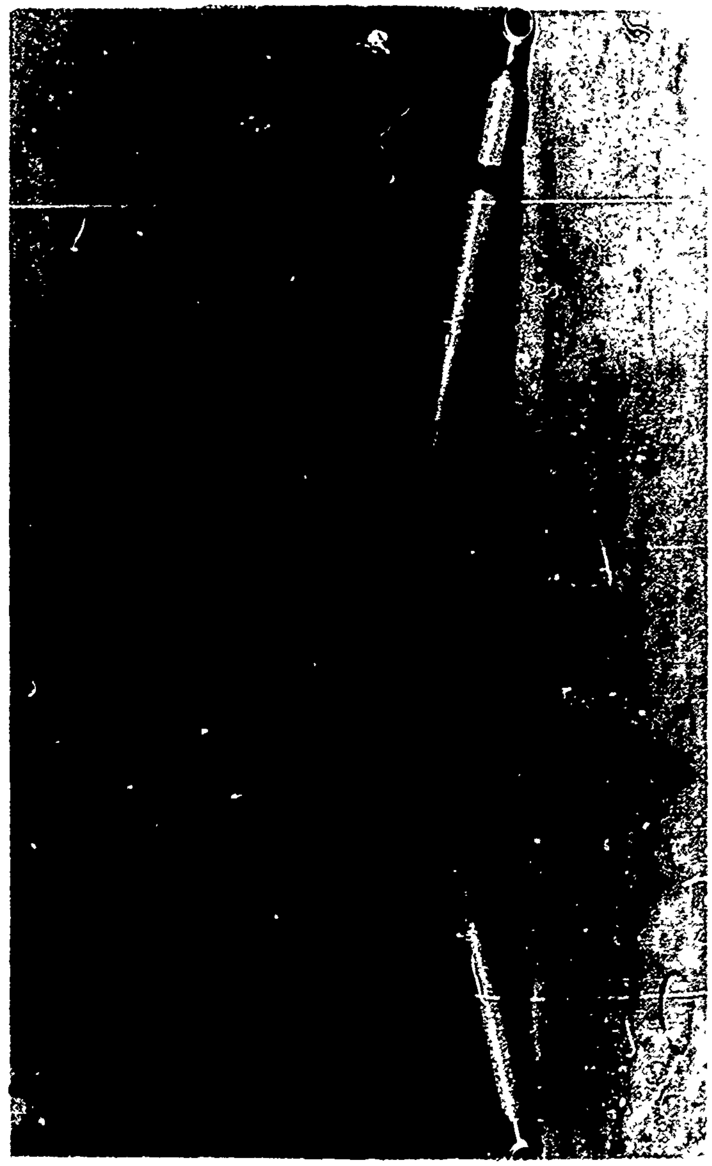

Figure 12. CH-47A 114C1013-8 Link Assembly--Failure at 94 percent Dul

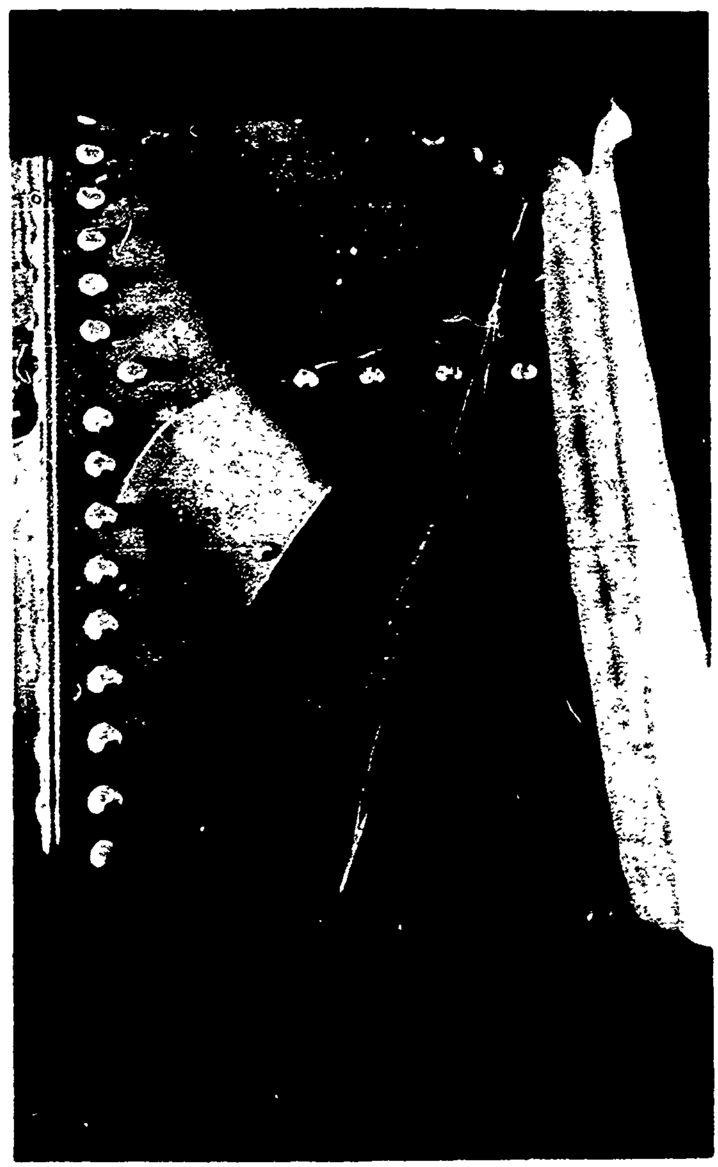

Figure 13. Condition VB Aft Obstruction--Shear Failure in Outboard Shear Panel of Right Aft Gear Shear Box

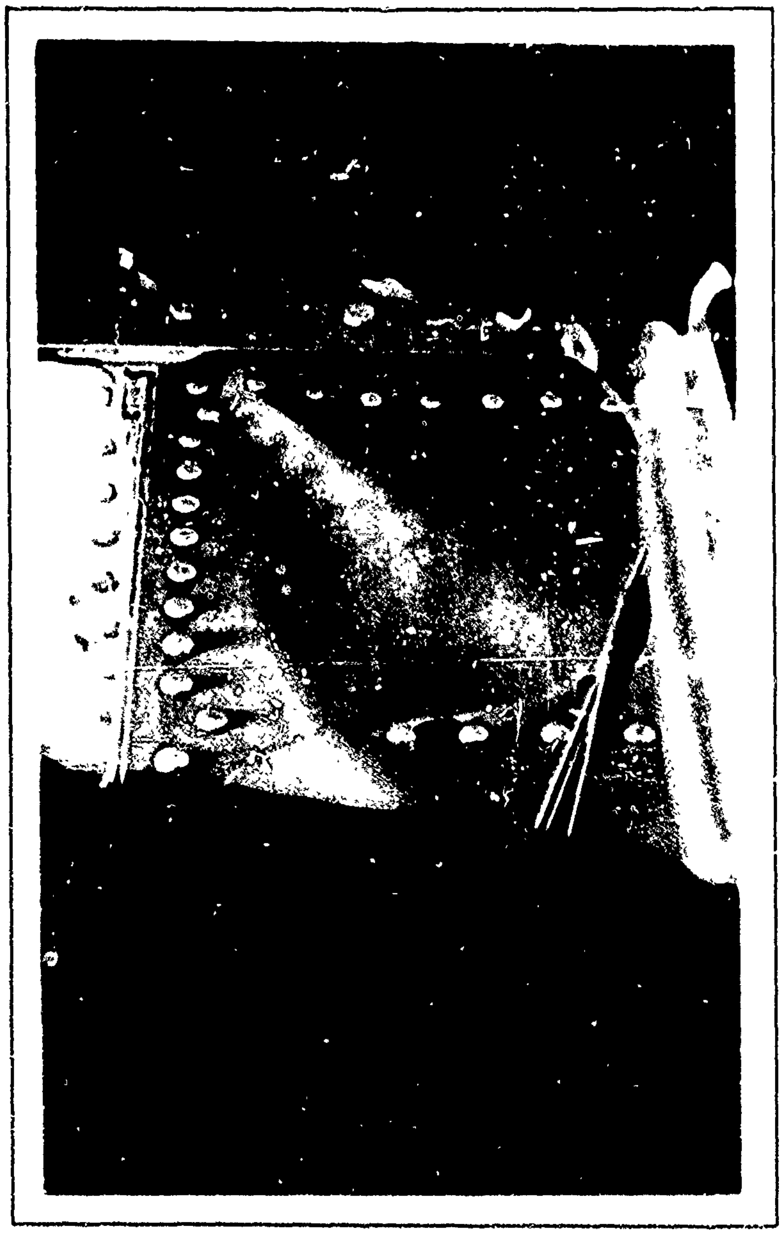

Figure 15. Condition VB Failure in Outboard Shear Panel of Right Aft Gear Shear Box

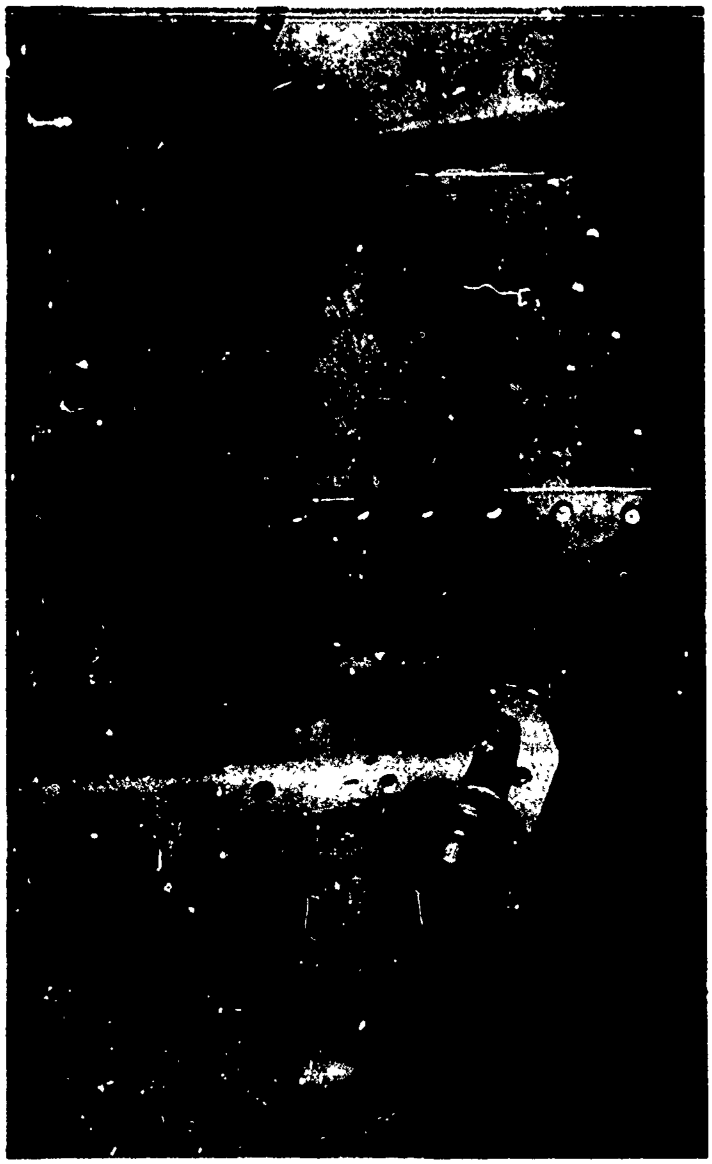

Figure 15. Buckling of Part No. 114S3351 at Frame 440 BL-20

Figure 16. Buckling of Part No. 114S3351 at Frame 482 BL-20

Figure 17. Failure of Litter Stanchion

Figure 18. Test Set-Up (Failure at Arrow)

Figure 19. Failure of FDC 4145

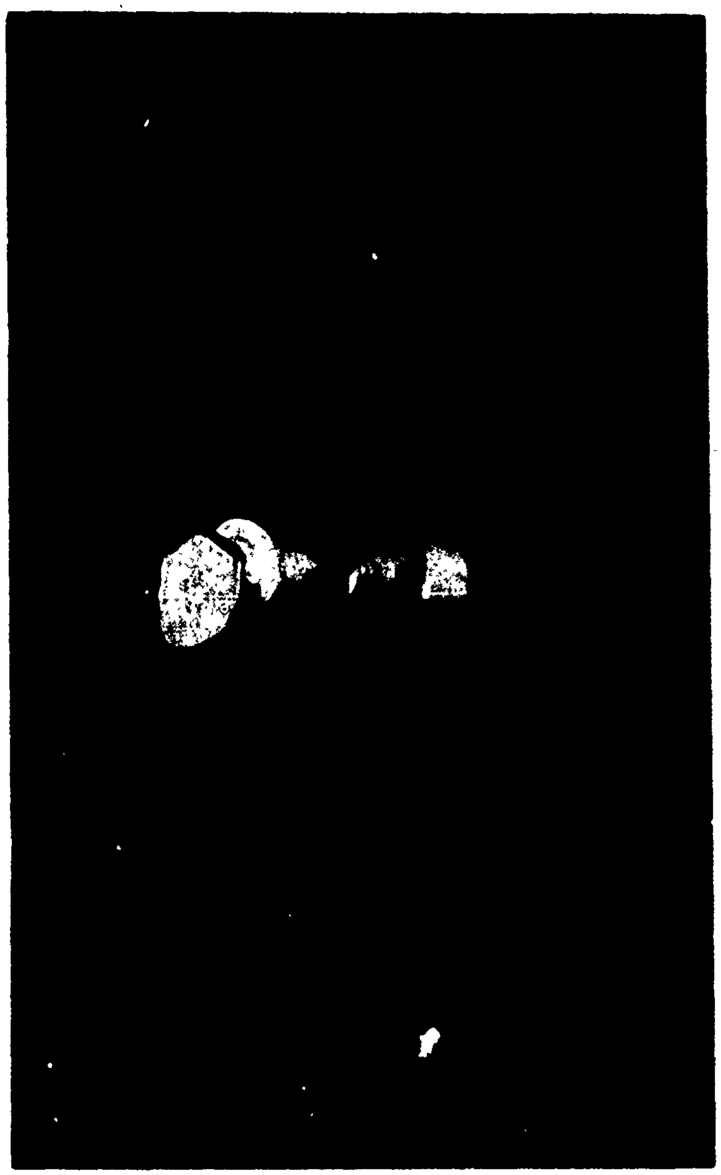

Figure 20. Failure of Aft Sliding Leg of Crew Seat

Figure 21. Position of Crew Seat Legs in the Most Forward Position

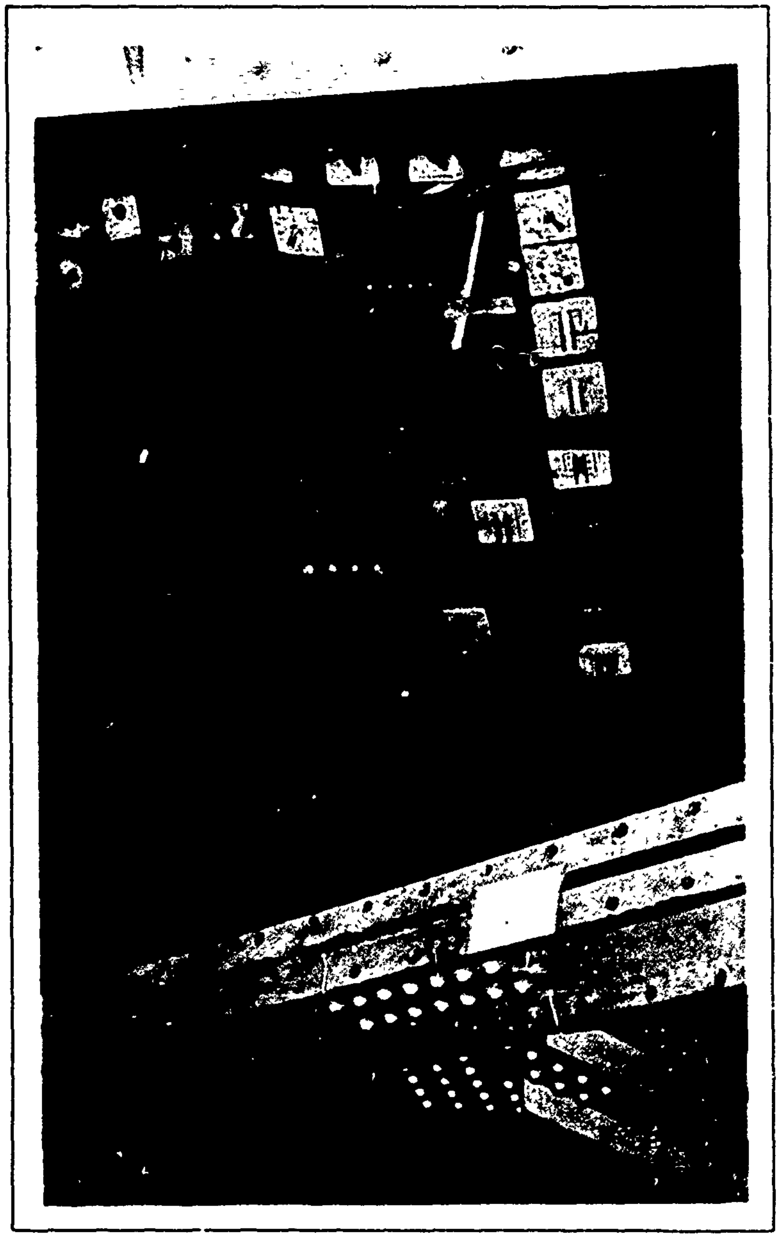

Figure 22. Condition 2B 140 percent (Run No. 2) Forward Fuselage Section at 140 percent

Figure 23. Condition 3B 140 percent DUL--Failure of Frames 555,575.5 and 594 and Rivet Scar in Beaded Web Which Attaches to Longeron 114S3356-17 (View Looking Up)

Figure 24. Condition 3B 140 percent FUL--Failure of Beaded Web Which Attaches to Longeron 114S3356-17 (View Looking Aft)

Figure 25. Condition 3B 140 percent DUL--Skin Tear and Permanent Buckle at Station 594 (View Looking Inboard)

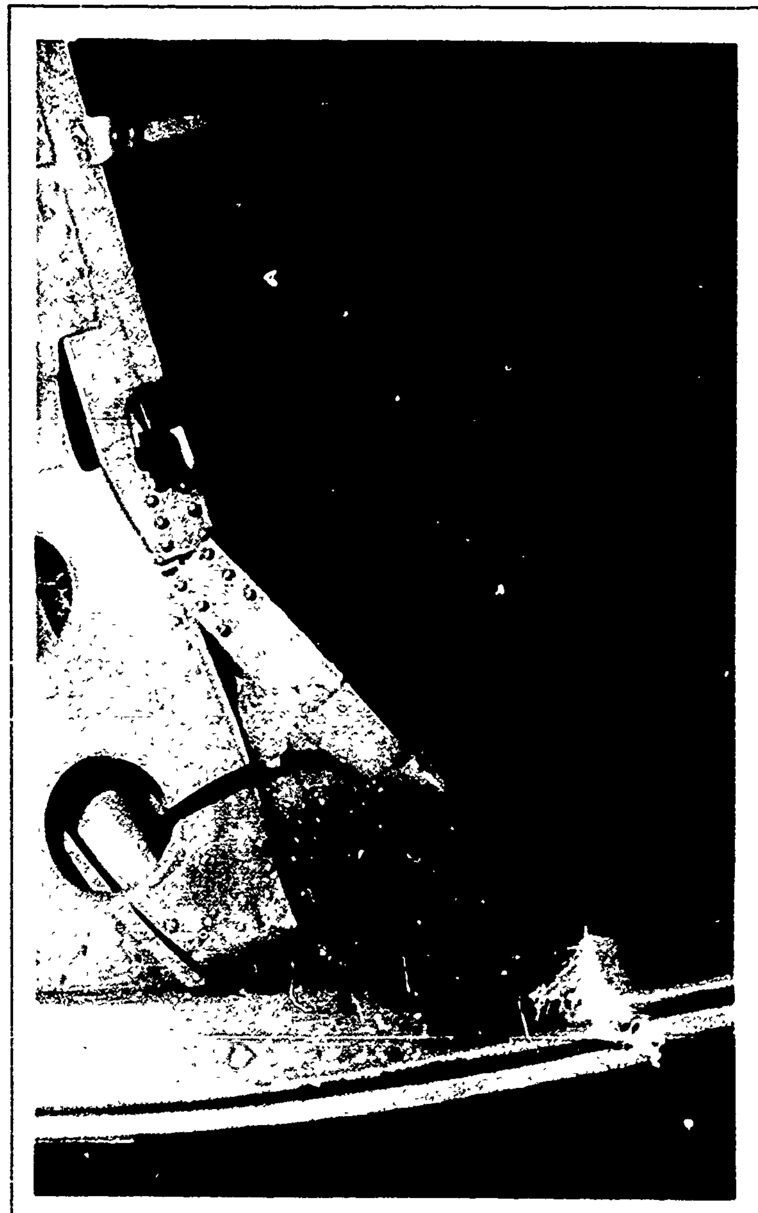

Figure 26. Condition 3B 140 percent DUL--Failure of Frame 594 (View Looking Up)

Figure 27. Condition 3B 140 percent DUL--Failure of Frame 534 (View Looking Forward)

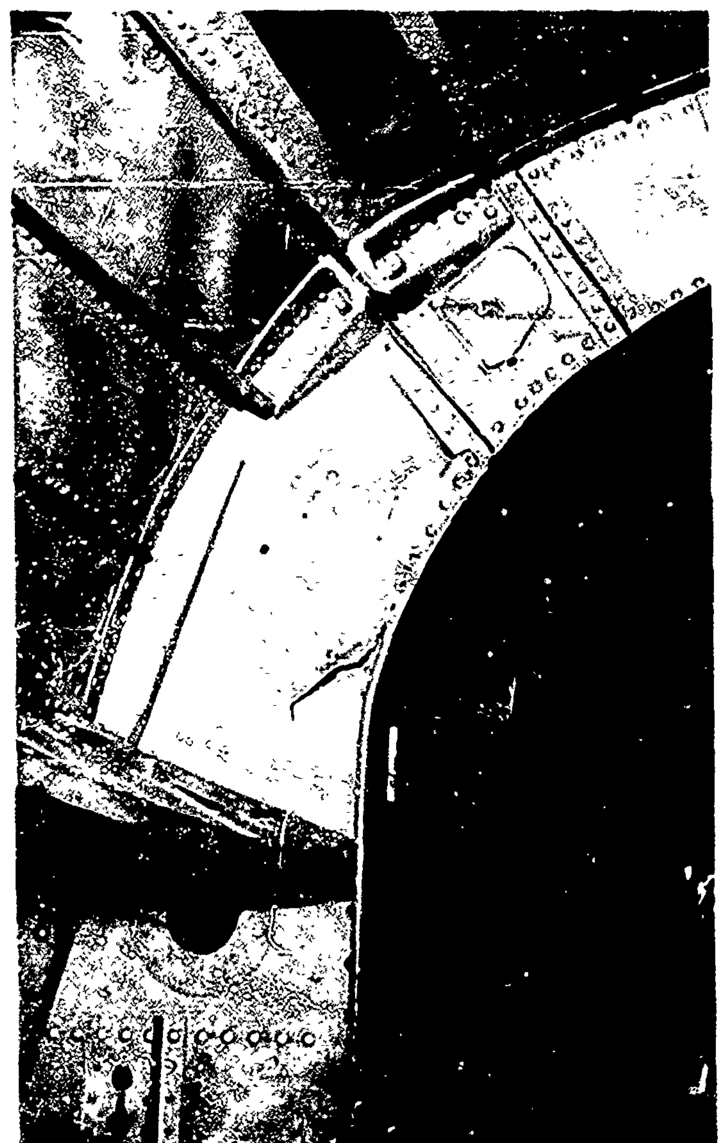

Figure 28. Condition 3B 140 percent DUL--Failure of Frame 534 (View Looking Aft)

Figure 29. Condition 3B 140 percent DUL--Failure of Ramp Fairing Aft of FS 482
(View Looking Forward)

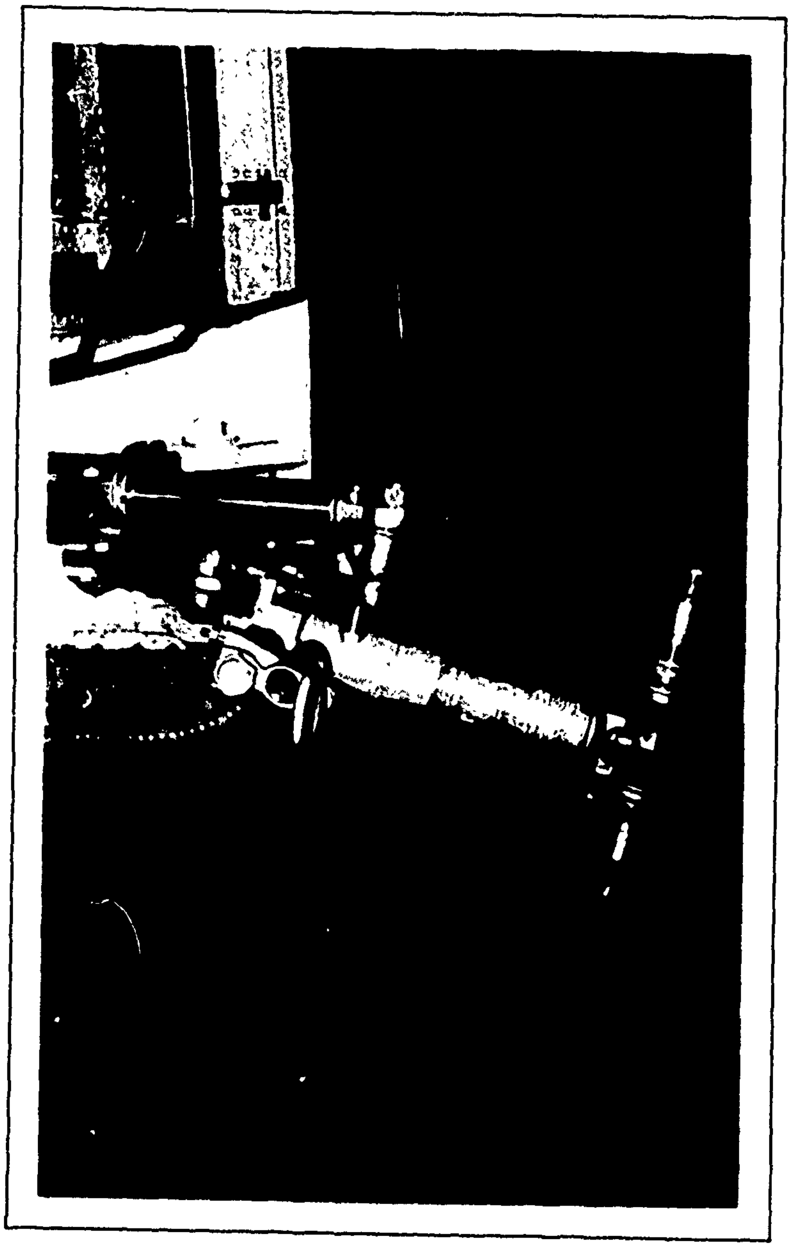

Figure 30. Condition VC--Failure of Aft Gear at 127 percent DUL

Figure 31. Condition VC--Failure of Drag Link 114L2029-1 at 127 percent DUL

Figure 32. Condition VC--Failure of Drag Link 114L2029-1

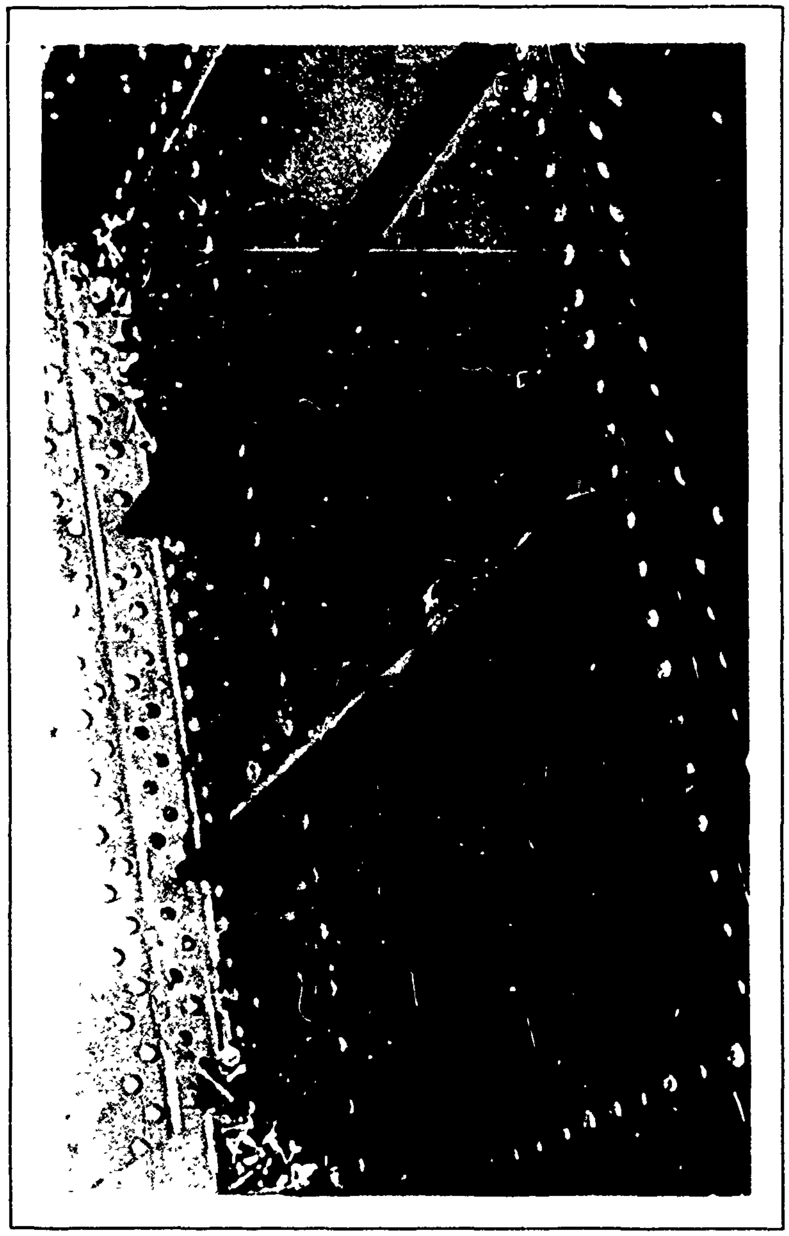

Figure 33. Wrinkles in New Web Installation